REMARKS

This amendment is responsive to the Office Action of September 21, 2006. Reconsideration and allowance of claims 3-5 and 9-21 are requested.

The Office Action

Claims 1-10 stand rejected under 35 U.S.C. § 102 as being anticipated by Lai ("Reconstructing NMR Images from Projections Under Inhomogeneous Magnetic Field and Non-Linear Field Gradients").

The Prior Art

In Lauterbur's 1973 proposal for magnetic resonance imaging, he proposed to apply magnetic field gradients in each of a plurality of radial directions around an axis of a subject parallel to the B_0 field to create a plurality of projections which are mathematically analogous to individual CT scan projections. To generate a projection in a first direction, an x-gradient with a fixed (linear) profile and a y-gradient with the same fixed profile are applied. By adjusting the relative amplitude (but not the profile), the projection direction is rotated. He then proposed to use a filtered backprojection reconstruction technique commonly used in CT scanners. As pointed out in the introduction to the article, this filtered backprojection technique has numerous advantages including advantages relative to the 2D and 3D Fourier transform reconstruction technique of Kumar, Welti, and Ernst.

On the other hand, the Fourier transform reconstruction technique has a very important advantage relative to filtered backprojection which led Fourier transform reconstruction to become the standard for commercial MRI systems. Filtered backprojection is very sensitive to non-uniformities. Any non-linearities in the main B_0 magnetic field and any non-linearities in the magnetic field gradients caused serious defects in the resultant images.

Unfortunately, in 1982, when the Lai paper was written, the hardware was not available to generate magnetic field gradients of the desired uniformity and linearity. Although the gradients were as linear as possible, rather than straight lines, they would be somewhat curved or bowed lines, such as shown in Figure 3 of Lai.

These gradients did not have sine waves or other complex patterns in the imaging region. Because the spatial position is encoded with the strength of the magnetic field, if the magnetic field gradient has the same strength at two or more locations, those locations cannot be discriminated. The locations with the same field strength all generate resonance signals of the same frequency, creating ambiguity in their spatial dependencies. Lai was not working with gradients that were so non-linear that he was concerned with ambiguous spatial dependencies.

Rather, Lai proposed to map curvature of each of the x, y, and z-magnetic field gradients. Lai then proposed to **backproject along curved paths** (page 934, last paragraph; page 937, lines 1-5).

Further, in Lai, the curvature of each of the x, y, and z-gradient components was mapped in a precalibration procedure. This determined the single non-linearity or curve for each component. Lai consistently applied gradients with the same curvature for each component in every repetition and could thus apply the same correction technique and use the same curve to define the projection path. There is no suggestion of changing the curve or spatial dependency of the gradients in each or subsequent repetitions.

It should also be noted that while Lai acknowledges that Kumar et al. have exemplary magnetic resonance imaging articles, the Lai article never mentions Fourier transform reconstruction nor makes any suggestion that any of the subject matter of the article would be applicable to Fourier transform reconstruction. Indeed, since a central point of the Lai technique is backprojecting along curved paths, it is submitted that the Lai technique is not applicable to Fourier transform reconstruction. Analogously, there is no suggestion of using the Lai technique with SENSE or other undersampled techniques or techniques which acquires magnetic resonance signals in a sub-sampling fashion. Moreover, because the undersampling techniques do not project along paths in the sense of Lai, it is submitted that there is no enabling disclosure as to how or if one might adapt the Lai technique to SENSE and other undersampled imaging techniques.

The Present Application

The present application is not concerned with correcting for almost linear, but slightly curved, gradients. Rather, the present technique can use gradients like the G_1 gradient of Figure 3 which oscillate and create spatial ambiguity. Other gradients with different spatial dependencies relative to the same axis are applied to create additional data with different spatial position dependency ambiguities. This enables the spatial ambiguities to be resolved.

In order to change the gradient profile in subsequent repetitions, a plurality of conductor systems, e.g. A, B, C. and D, are provided at different positions along the z-axis. Each is separately controlled to create different gradient profiles in the z-direction (page 6, first full paragraph).

To accelerate reconstruction, the present application further suggests the use of SENSE or other undersampled imaging techniques.

The Claims Distinguish Patentably Over the References of Record

Claim 3 calls for the magnetic resonance signals to be subsampled. Lai does not teach or fairly suggest reconstruction using SENSE or other undersampled imaging techniques in which sub-sampled magnetic resonance signals are reconstructed into a magnetic resonance image based on the spatial sensitivity profiles of the array of receiving antenna. To the contrary, the Lai technique provides an enabling disclosure only with respect to filtered backprojection reconstruction techniques. That is, Lai cures the non-linear gradient problem by Backprojecting along a curved path (curved to match the non-linearity). Because there is no analogous backprojection in undersampled techniques, Lai provides no teaching as to how they could (or if they even should) address non-linear gradients.

Further, claim 3 calls for the application of N field patterns where N is larger than 3. In Lai, it appears that the hardware can apply three field patterns, an x-pattern, a y-pattern, and a z-pattern, each of which is fixed and of the same pattern every time it is applied. The projection direction is rotated by adjusting the relative amplitude of the x and y-gradients, but not their patterns.

Accordingly, it is submitted that **claim 3 and claims 4, 5, 11, 12, 13 and 14 dependent therefrom** are not anticipated by Lai.

Further, **claims 4 and 5** address distinguishing fold-over artifacts. The Lai technique does not address or recognize fold-over artifacts.

Claim 11 addresses oscillating filed patterns; whereas, Lai addresses gradients that are substantially linear with a small amount of arc. **Claim 12** calls fothe position dependent field patterns to be encoded in at least four dimensions; whereas Lai only addresses two or z-dimensions. **Claim 13** calls for changing the spatial dependency along one of the axes; whereas, Lai keeps the gradient profile constant.

Claim 9 calls for magnetic fields with different position dependencies relative to at least one of the dimensions to be applied. In Lai, the spatial dependencies of the magnetic field gradient relative to each axes is fixed and remains the same in each application of it. Further, Lai teaches that non-linearity in the magnetic field is bad and should be avoided, and that it should be corrected when it inherently exists. By contrast, the present technique purposefully applies non-linear magnetic fields and applies magnetic fields with different spatial dependencies along a given axis.

Accordingly, it is submitted that **claim 9 and claim 10 dependent therefrom** distinguish patentably and unobviously over the references of record.

Claim 15 calls for applying a plurality of different position-dependent field patterns along at least one axis or spatial coordinate. By contrast, Lai consistently applies a profile of a fixed shape along each axis or coordinate. Accordingly, it is submitted that **claim 15 and claims 16-21 dependent therefrom** are not anticipated by Lai and distinguish patentably thereover.

Claims 18 and 19 call for using an undersampled imaging technique, such as SENSE. By contrast, Lai provides an enabling disclosure only with regard to filtered backprojection imaging techniques.

Claim 20 calls for more than 3 gradient subsystems; whereas, Lai has x and y-subsystems and may a z-subsystem. Accordingly, it is submitted that **claims 15-21** are not anticipated by and distinguish patentably over the references of record.

CONCLUSION

For the reasons set forth above, it is submitted that claims 3-5 and 9-21 distinguish patentably over the references of record and meet all statutory requirements. An early allowance of all claims is requested.

In the event the Examiner considers personal contact advantageous to the disposition of this case, she is requested to telephone Thomas Kocovsky at (216) 861-5582.

Respectfully submitted,

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